

Production Efficiency Analysis of Karnal Cooperative Sugar Mills Ltd.: A Geographical Study

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Received: 24 Jan 2025; Received in revised form: 22 Feb 2025; Accepted: 26 Feb 2025

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Abstract

This study examines the production efficiency of Karnal Cooperative Sugar Mills Ltd. with reference to installed capacity, capacity utilisation, operational area, crop days, cane crushed, sugar production, and sugar recovery. The analysis is based on selected crushing seasons and employs percentage and trend-based evaluation methods to assess operational performance. The findings reveal significant expansion in installed capacity over time, indicating infrastructural growth and modernisation. However, variations in capacity utilisation and crop days reflect fluctuations in operational consistency. The relationship between cane crushed and sugar production demonstrates stable input-output efficiency, while recovery trends indicate moderate technical stability. Overall, the study highlights that sustained improvement in operational coordination and command-area management is essential to enhancing long-term production efficiency.

Keywords— Recovery Trends, Production Efficiency, Command Area, Operational Performance.

I. INTRODUCTION

Production efficiency is a central concept in industrial and agricultural economics that explains how effectively an enterprise transforms inputs into outputs. In its simplest form, production efficiency exists when maximum possible output is produced from a given quantity of inputs, or when a specific level of output is achieved using the least possible inputs (Farrell, 1957). The concept is deeply rooted in classical and neoclassical economic theory, where efficiency reflects optimal utilisation of resources under technological and managerial constraints.

In agro-based industries, production efficiency assumes greater significance because they are directly dependent on agricultural cycles, climatic conditions, and the quality of raw materials. The sugar industry, in particular, operates under seasonal constraints, with the crushing season (crop days) determining the time-bound processing of perishable sugarcane. Delays or inefficiencies during the crushing period may result in sucrose loss, reduced recovery rates, and financial inefficiencies.

According to the Food and Agriculture Organisation of the United Nations, agro-processing efficiency enhances value addition, reduces post-harvest losses, and strengthens rural

economies by linking agriculture with industry (FAO, 2017). Thus, production efficiency in cooperative sugar mills is not merely an internal performance measure but also a broader developmental indicator that influences farmers' incomes, employment generation, and regional economic growth.

II. CONCEPT OF PRODUCTION EFFICIENCY IN AGRO-BASED INDUSTRIES

The concept of production efficiency in agro-based industries integrates technical performance, managerial capability, and raw material quality. Unlike purely manufacturing industries, agro-based industries depend on biological inputs whose quality varies across seasons and regions. Therefore, efficiency must be analysed in relation to both input quantity and input quality.

Farrell (1957) introduced the framework of technical efficiency measurement through the production frontier approach, which remains foundational in productivity analysis. Later, Coelli et al. (2005) expanded this framework by integrating stochastic frontier models and data envelopment analysis to measure efficiency in

agricultural and agro-industrial sectors. These approaches highlight that inefficiency may arise due to suboptimal technology, poor management, inadequate infrastructure, or irregular raw material supply.

In the sugar industry, production efficiency is generally assessed using operational indicators such as cane crushed per day, sugar recovery percentage, and total sugar output. The National Federation of Cooperative Sugar Factories Limited emphasises that higher recovery rates and optimal utilisation of crushing capacity are key determinants of financial viability and operational stability (NFCSF, 2022).

Moreover, agro-based industries must manage logistical and spatial dimensions, particularly the operational or command area from which raw materials are procured. Inefficient coordination within the operational area can increase transportation costs, reduce cane freshness, and ultimately affect recovery rates. Therefore, production efficiency in cooperative sugar mills is multidimensional—covering technological, spatial, managerial, and agricultural dimensions.

III. IMPORTANCE OF EFFICIENCY IN COOPERATIVE SUGAR MILLS

Efficiency is particularly important in cooperative sugar mills, which are structured around collective ownership and farmer participation. Unlike private enterprises that primarily aim to maximise profits, cooperative mills balance commercial objectives with socio-economic welfare. Their sustainability depends on maintaining operational efficiency while ensuring fair returns to farmer-members.

The National Cooperative Development Corporation notes that the long-term viability of cooperative agro-industries depends on sound financial management, technological upgradation, and optimal capacity utilisation (NCDC, 2021). Inefficiency may lead to higher production costs, delayed payments to farmers, mounting debts, and reduced credibility within the operational area.

Efficient cooperative sugar mills contribute significantly to rural employment, local infrastructure development, and income stability. The Food and Agriculture Organisation of the United Nations highlights that efficient agro-processing industries act as engines of rural transformation by generating forward and backward linkages in the agricultural economy (FAO, 2017).

In the context of sugar mills, efficiency ensures:

- i. Maximum utilisation of crop days
- ii. Optimal crushing capacity

- iii. Improved sugar recovery rates
- iv. Stable cane procurement within operational areas
- v. Financial sustainability and timely farmer payments

Therefore, production efficiency in cooperative sugar mills is not only an indicator of industrial performance but also a determinant of rural economic resilience and cooperative sustainability. For empirical analysis, variables such as crop days, cane crushed, sugar production, sugar recovery, and operational area collectively provide a comprehensive framework to assess efficiency trends over time.

IV. OBJECTIVES

- i. To examine the trend of installed capacity and its utilisation in the mill.
- ii. To assess overall production efficiency based on selected operational variables.

V. RESEARCH METHODOLOGY

The study is based on secondary data from official records of Karnal Cooperative Sugar Mills Ltd. and relevant cooperative sugar-sector reports. The analysis covers selected crushing seasons and focuses on key variables, including installed capacity, capacity utilisation, operational area, crop days, cane crushed, sugar production, and sugar recovery. Simple statistical tools, including percentage analysis and comparative assessment, were used to examine production efficiency. The relationship between input (cane crushed) and output (sugar production) was evaluated to understand technical performance. All the graph-related work has been done using MS Excel 2019. The methodology is both descriptive and analytical.

VI. PROFILE OF KARNAL COOPERATIVE SUGAR MILLS LTD.

Karnal Cooperative Sugar Mills Ltd., established in 1977, is a major cooperative agro-industrial unit in Haryana. At the time of its establishment, the mill had an initial installed crushing capacity of 1250 tonnes of cane per day (TCD). The creation of the mill was aimed at ensuring assured procurement of sugarcane from farmers within its operational (command) area and at strengthening the agro-industrial base of Karnal district (Official Website of Karnal Sugar Mills Ltd, 2024).

Over time, in response to increasing sugarcane production and the need for higher processing efficiency, the mill underwent capacity expansion. By the crushing season 2022–23, its installed capacity had increased to 3500 TCD,

reflecting substantial technological and infrastructural development. This expansion indicates improved industrial capability, better handling of cane supply, and enhanced production potential.

The mill functions under the supervision of the Haryana State Federation of Cooperative Sugar Mills Ltd., which coordinates operational, financial, and technical matters of cooperative sugar mills in Haryana. According to the National Cooperative Development Corporation, cooperative sugar mills play a vital role in promoting rural industrialisation and ensuring farmer-centric industrial growth (NCDC, 2021). In this context, the increase from 1250 TCD to 3500 TCD demonstrates the mill's evolving production efficiency and institutional strengthening over four decades.

6.1 Installed Capacity in the Mill

Installed capacity refers to the maximum quantity of sugarcane that a mill is technically designed to crush within a specified period under normal operating conditions. It reflects the scale of industrial infrastructure, the efficiency of machinery, and processing capability. In cooperative sugar mills, installed capacity determines production planning, operational scheduling, and overall performance efficiency, and it plays a crucial role in

balancing cane supply with crushing operations during the season.

Table No. 1: Installed Capacity and Capacity Utilisation (2010-11 to 2022-23)

Seasons	Installed Capacity (TCD)	Capacity Utilisation (%)
2010–11	2200	99.44
2016–17	2200	88.15
2022–23	3500	88.05

Source: Sugarfed Haryana, 2025

The data indicates notable changes in installed capacity and its utilisation over time. In the 2010–11 season, the mill operated with a stable installed capacity and achieved very high-capacity utilisation, suggesting efficient use of available crushing infrastructure. This reflects effective coordination between cane procurement and processing operations during that season.

In 2016–17, although the installed capacity remained unchanged, capacity utilisation declined. This variation may be attributed to fluctuations in cane availability, operational constraints, or seasonal factors affecting crushing performance.

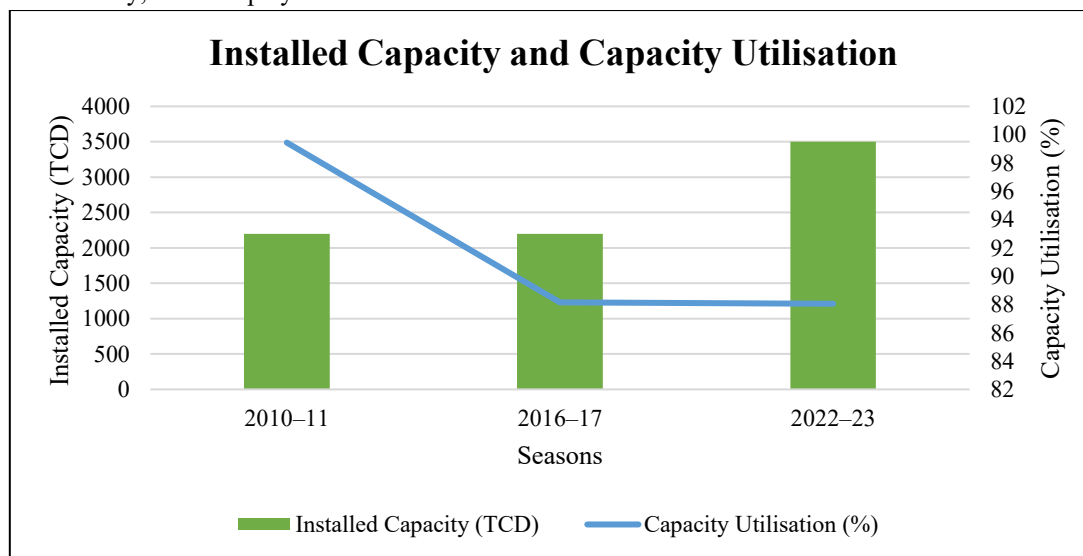


Fig. No. 1: Installed Capacity and Capacity Utilisation (2010-11 to 2022-23)

Source: Based on Table No. 1

By 2022–23, the mill significantly expanded its installed capacity, indicating infrastructural modernisation and technological upgradation. However, the utilisation rate remained relatively low, suggesting that while production potential increased, full operational optimisation was not fully achieved. Overall, the trend highlights expansion in

processing capability accompanied by variable efficiency in capacity utilisation across seasons.

6.2 Operational Area (Cane Command Area) of the Sugar Mill

The operational area, also known as the cane command area, refers to the geographically designated region from which a sugar mill procures sugarcane for processing. This

area includes villages and agricultural fields allocated to the mill for assured procurement. A well-defined operational area ensures a systematic supply of cane, reduces transportation delays, maintains cane freshness, and supports efficient crushing operations throughout the production season.

Table No. 2: Operational Area (2010-11 to 2022-23)

Seasons	Operational Area (Command Area) (% to Total)
2010-11	10.97
2016-17	7.12
2022-23	9.87

Source: Sugarfed Haryana, 2025

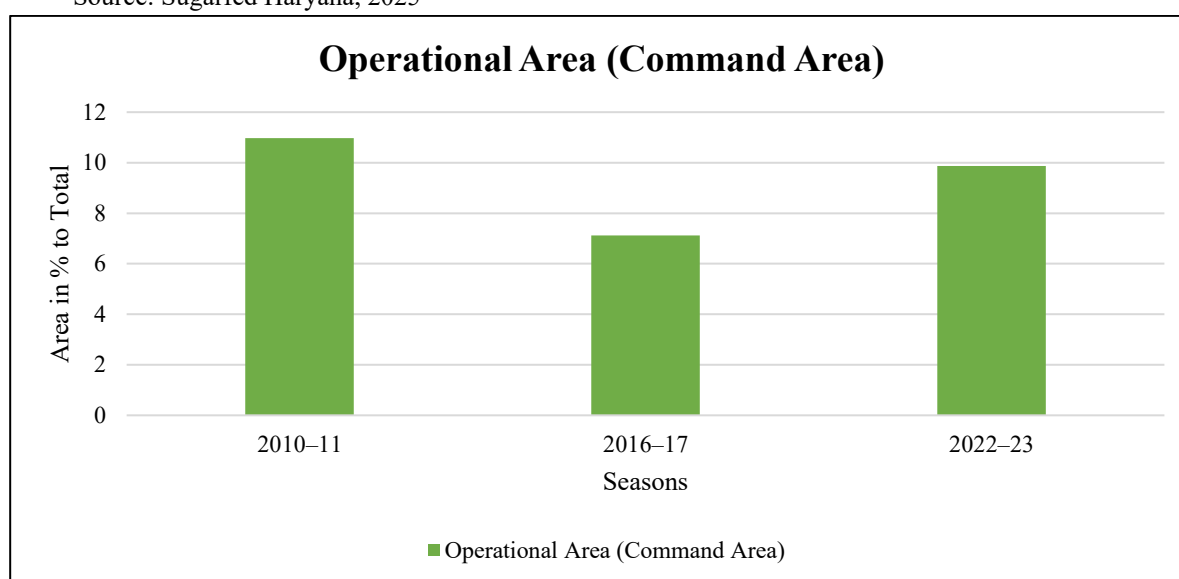


Fig. No. 2: Operational Area (2010-11 to 2022-23)

Source: Based on Table No. 2

By 2022-23, the operational area share increased again, reflecting recovery in cane coverage and improved procurement coordination. Overall, the trend indicates fluctuations in spatial coverage but demonstrates the mill's continued effort to stabilise its cane command area to support sustained production efficiency.

6.3 Crop Days and Crushing Performance

Crop days refer to the total number of days during which a sugar mill operates its crushing activities in a particular season. Crushing performance is closely linked to the duration and efficiency of these operational days. Longer and well-managed crop periods generally allow better utilisation of installed capacity and improved coordination between cane procurement and processing. Efficient crushing performance depends on timely cane supply, reliable machinery, effective labour management, and

The operational (cane command) area data of Karnal Cooperative Sugar Mills Ltd. shows moderate variation across the selected seasons. In 2010-11, the mill accounted for a relatively higher share of the total operational area, indicating broader cane procurement coverage and stronger command over its designated villages. This wider coverage likely supported a stable cane supply and efficient crushing operations.

In 2016-17, the percentage declined noticeably, suggesting a contraction in the effective command area or reduced cane availability within the allotted region. Such variation may be influenced by inter-mill competition, shifting farmer preferences, crop diversification, or climatic factors affecting sugarcane cultivation.

minimal operational interruptions. Variations in crop days may arise from climatic conditions, cane availability, technical breakdowns, or administrative constraints, all of which directly affect overall production efficiency.

Table No. 3: Crop Days (2010-11 to 2022-23)

Seasons	Crop Days
2010-11	138
2016-17	201
2022-23	175

Source: Sugarfed Haryana, 2025

The crop days of Karnal Cooperative Sugar Mills Ltd. show noticeable variation across the selected seasons, reflecting changes in crushing duration and operational

intensity. In 2010–11, the mill operated for a comparatively shorter crushing period, which may indicate

limited cane availability or an earlier season closure.

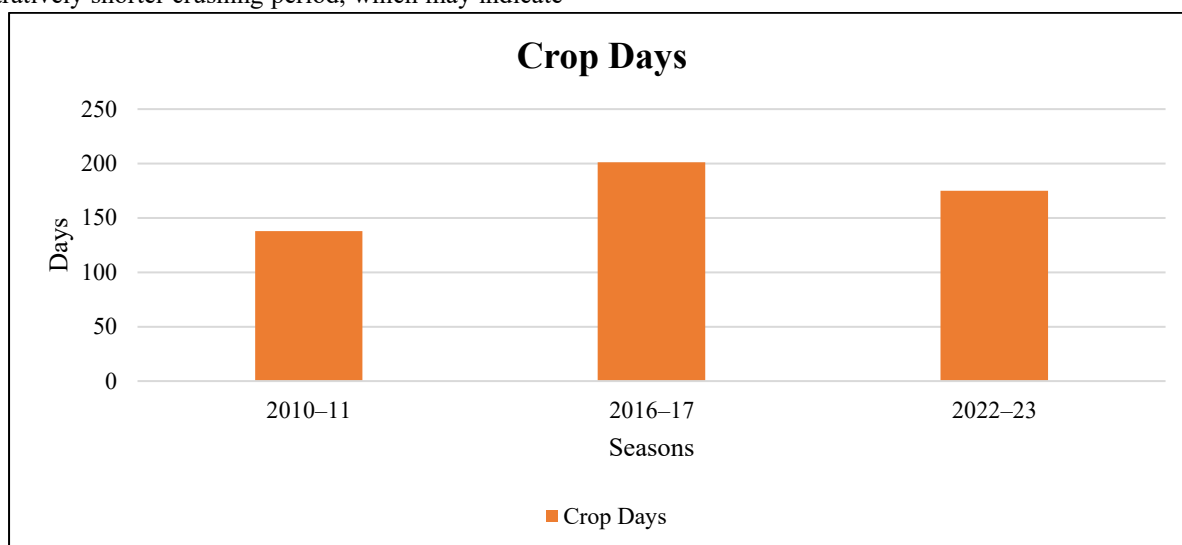


Fig. No. 3: Crop Days (2010-11 to 2022-23)

Source: Based on Table No. 3

In 2016–17, crop days increased substantially, suggesting improved cane supply, better coordination within the operational area, and extended crushing operations. A longer crushing season generally enhances capacity utilisation and allows greater processing of available cane, contributing positively to production performance.

However, in 2022–23, crop days declined moderately compared to the previous peak. This reduction may be associated with factors such as fluctuations in cane production, climatic variability, or improved efficiency, allowing quicker crushing within fewer days. Overall, the trend highlights dynamic operational management and its direct impact on crushing performance and production efficiency.

6.3.1 Factors Affecting Duration of Crushing Season

i. Availability of Sugarcane Supply

The total area under sugarcane cultivation and overall yield directly determine how long the mill can continue crushing operations. Lower cane production shortens the season, while an abundant supply extends it.

ii. Climatic and Weather Conditions

Rainfall, temperature, frost, and unseasonal weather conditions influence cane maturity and harvesting schedules, thereby affecting the duration of the crushing season.

iii. Installed Capacity and Machinery Efficiency

Higher installed capacity and well-maintained machinery enable faster crushing, potentially reducing the number of

crop days, whereas technical breakdowns may prolong or interrupt operations.

iv. Operational Area Management

Effective coordination within the cane command area ensures timely harvesting and transportation, helping maintain a steady flow of cane throughout the season.

v. Labour Availability and Administrative Planning

Adequate labour supply, efficient scheduling, and sound managerial decisions are crucial to sustaining uninterrupted crushing operations.

vi. Government Policies and Inter-Mill Competition

Pricing policies, procurement regulations, and competition from nearby mills can influence farmer supply patterns, thereby impacting the length of the crushing season.

6.4 Cane Crushed and Sugar Production Analysis

Cane crushed represents the total quantity of sugarcane processed by a mill during a crushing season, while sugar production refers to the final output obtained after processing. The relationship between these two variables underlies production performance in the sugar industry. Efficient conversion of cane into sugar depends on raw material quality, recovery rate, machinery efficiency, and operational management. Variations in cane supply directly influence production levels, as inadequate procurement can limit output despite available installed capacity. Therefore, analysing cane crushed alongside sugar production provides a clear understanding of input–output efficiency and overall operational effectiveness.

Table No. 4: Cane Crushed and Sugar Production (2010-11 to 2022-23)

Seasons	Cane Crushed	Sugar Production
2010–11	13.23	14.60
2016–17	7.87	8.68
2022–23	12.22	12.64

Figures are in % to Total

Source: Sugarfed Haryana, 2025

The data for Karnal Cooperative Sugar Mills Ltd. shows a clear correspondence between cane crushed and sugar production across the selected seasons. In 2010–11, a higher quantity of cane was processed, resulting in a proportionately higher level of sugar production. This

indicates effective input–output conversion and stable operational efficiency during that period.

In 2016–17, both cane crushed and sugar production declined significantly. The simultaneous reduction suggests either lower cane availability, shorter effective crushing performance, or variations in recovery efficiency. Such fluctuations highlight the sensitivity of production to raw material supply and operational conditions.

By 2022–23, cane crushing levels improved again, accompanied by a corresponding rise in sugar output. The parallel movement of these variables demonstrates a strong functional relationship between raw material intake and final production. Overall, the trend reflects cyclical variations in supply and performance while maintaining consistent conversion efficiency.

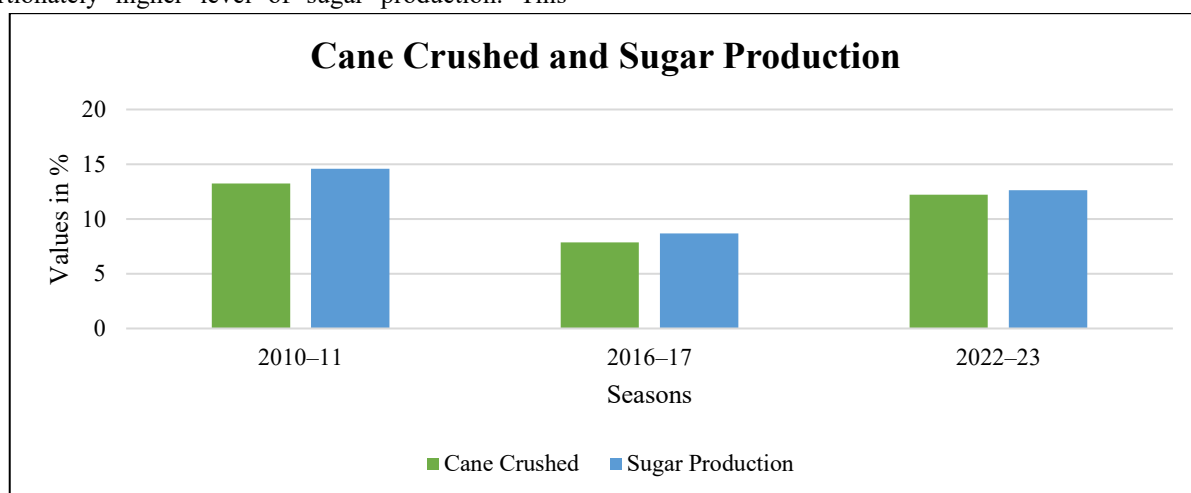


Fig. No. 4: Cane Crushed and Sugar Production (2010-11 to 2022-23)

Source: Based on Table No. 4

6.5 Sugar Recovery and Technical Efficiency

Sugar recovery and technical efficiency are closely interconnected in the sugar industry. Recovery rate reflects the proportion of sugar extracted from the total quantity of cane crushed, while technical efficiency indicates how effectively machinery, labour, and processing systems convert raw material into final output. Higher recovery generally signifies better utilisation of technological infrastructure and improved production management. Variations in recovery often arise from cane quality, the time lag between harvesting and crushing, and operational precision within the mill.

i. Concept of Recovery Rate

Recovery rate refers to the percentage of sugar obtained from a given quantity of sugarcane during processing. It is a crucial indicator of mill performance because it

measures sucrose extraction efficiency. Recovery is influenced by factors such as cane maturity, sucrose content, milling technology, maintenance of machinery, and processing time. A higher recovery rate reflects better technical efficiency, reduced wastage, and effective coordination between procurement and processing. Therefore, the recovery rate is a key parameter for evaluating a sugar mill's overall productivity and technological performance.

Table No. 5: Sugar Recovery (2010-11 to 2022-23)

Seasons	Sugar Recovery (%)
2010–11	9.30
2016–17	10.87
2022–23	9.76

Source: Sugarfed Haryana, 2025

The sugar recovery trend of Karnal Cooperative Sugar Mills Ltd. shows moderate fluctuation across the selected seasons, reflecting variations in technical performance and cane quality. In 2010–11, the recovery level was

stable, indicating satisfactory sucrose extraction under prevailing operational conditions.

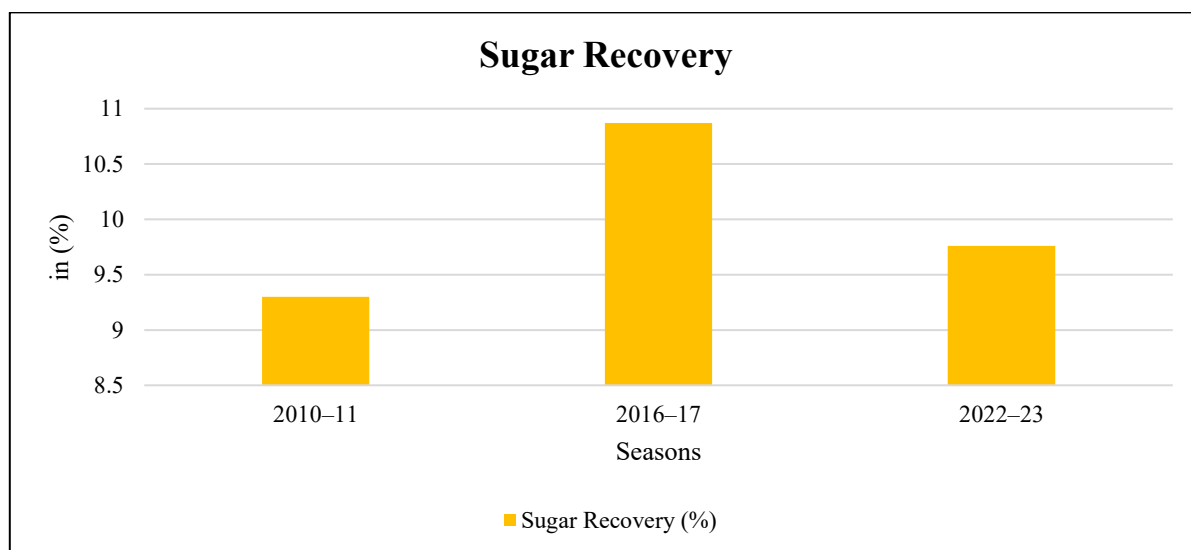


Fig. No. 5: Sugar Recovery (2010-11 to 2022-23)

Source: Based on Table No. 5

In 2016–17, recovery improved significantly, suggesting better cane quality, efficient milling operations, and improved technical management. Higher recovery during this season may also reflect timely crushing of mature cane and effective maintenance of processing machinery, both of which enhance sucrose extraction efficiency.

However, in 2022–23, recovery declined slightly compared to the previous peak. This marginal reduction may be associated with variations in cane maturity, climatic influences, or minor operational inefficiencies. Despite this decline, the recovery rate remained within a reasonable range, indicating sustained technical capability. Overall, the trend demonstrates fluctuating yet stable technical efficiency over time.

VII. FINDINGS OF THE STUDY

The above analysis reveals significant insights into its production efficiency and operational performance over the selected seasons. The mill has demonstrated long-term infrastructural growth, reflected in the expansion of installed capacity, indicating institutional strengthening and technological modernisation. However, variations in capacity utilisation suggest that full optimisation of expanded capacity has not been consistently achieved.

The operational (cane command) area showed fluctuations, implying changes in cane coverage and procurement

dynamics. Such variations may have influenced the stability of raw material supply and overall crushing performance. Crop days displayed considerable variation, highlighting the mill's sensitivity to cane availability, seasonal conditions, and managerial coordination.

The analysis of cane crushed and sugar production confirms a strong positive relationship between input and output, indicating stable conversion efficiency. Sugar recovery trends suggest moderate fluctuations, reflecting changes in cane quality and technical performance, but overall recovery remained within an efficient operational range.

Collectively, the findings indicate that while the mill has expanded its physical capacity and maintained stable technical efficiency, operational consistency—particularly in capacity utilisation and command area management—remains a key determinant of sustained production efficiency.

VIII. CONCLUSION

The overall assessment of Karnal Cooperative Sugar Mills Ltd. indicates that the mill has experienced structural growth and technological advancement over time, particularly through expanded installed capacity. The analysis of crop days, cane crushed, sugar production, and recovery rate reflects a generally stable input–output

relationship, demonstrating satisfactory technical efficiency. However, fluctuations in capacity utilisation and operational area suggest that operational consistency remains a challenge. Variations in crushing duration and recovery levels highlight the influence of cane availability, climatic conditions, and managerial coordination. Overall, the mill exhibits moderate to strong production efficiency, but sustained optimisation of capacity and command area management is essential for enhancing long-term operational performance and stability.

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